The frontotemporal ("pterional") approach—an historical perspective

Tamer Altay, MD, and William T. Couldwell, MD, PhD

Department of Neurosurgery, University of Utah, Salt Lake City, Utah

Corresponding author: Tamer Altay, MD

Ozel Medicana International Ankara Hastanesi

Sogutozu Mah. 2165 Sok. No: 6

06520, Sogutozu, Ankara, Turkey

phone: 011-90-531-941-9726

fax: 011-90-312-292-9292

Email: altaytamer@hotmail.com

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Abstract

The frontotemporal, so-called "pterional" approach has evolved with the contribution of many neurosurgeons over the past century. It has stood the test of time and been the most commonly used transcranial approach in neurosurgery. In its current form, drilling the sphenoid wing as far down as the superior orbital fissure with or without the removal of the anterior clinoid, thinning the orbital roof, and opening the Sylvian fissure and basal cisterns are the hallmarks of this approach. Tumoral and vascular lesions involving the sellar/parasellar area, anterior and anterolateral circle of Willis, middle cerebral artery, anterior brain stem, upper basilar artery, insula, basal ganglia, mesial temporal region, anterior cranial fossa, orbit, and optic nerve are within the reach of the frontotemporal approach. In this paper, we review the origins, evolution, and modifications of the frontotemporal approach and update the discussion of some of the related derivative procedures.

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Introduction

Modern neurosurgical techniques have evolved with improved equipment and medical knowledge, but also because of the constant comparison and influence of the various techniques on one another over the years. For many techniques, preserving the balance between the need to minimize brain retraction and the need to maximize surgical exposure has been a driving force for advancement. Among the various composite approaches, the frontotemporo-sphenoidal (FTS) approach has been one of the most versatile and widely used in contemporary neurosurgery since it was popularized by Yasargil 40 years ago. It was originally proposed for the microsurgical treatment of cerebral aneurysms in the entire circle of Willis,[1, 2] but then was applied to the resection of various lesions and vascular malformations in the sellar, parasellar, temporal, and subfrontal areas as well as the anterior and anterolateral midbrain. The main components of the approach that contributed to its efficiency are that it offers a smaller craniotomy with less unnecessary exposure in the frontal and temporal lobes, it presents a wide frontobasal exposure because of extensive sphenoid bone drilling and a transsylvian dissection, enabling less brain retraction, and it gives quick access to the basal cisterns as well as the circle of Willis. Over time, the FTS approach has undergone variations, modifications, and extensions to expand its trajectory and increase the coverage of indications for more complex lesions. Among the most recognized variations of the FTS approach are the temporopolar, pretemporal, cranio-orbitozygomatic, and lateral supraorbital approaches. In this paper, we review the origins of the contemporary FTS approach and the journey of its creation, its indications and technique, its current versions, and its role in the improvement of surgical and clinical outcome.

Need for an anterior approach

As surgeons in the early 1900s began to recognize the effect of tumors of the pituitary gland, the treatment of some acromegaly cases in which the gland reached a large size demanded a search for a surgical approach that could be used safely and consistently. The credit for the first surgical exposure of the pituitary should be given to Sir Victor Horsley, who undertook surgical resection of a pituitary tumor in 1889.[3,4] In this procedure, he used an essentially frontal approach in which he simply tried to raise the frontal lobe; he had difficulty in achieving the appropriate exposure and determined that the tumor was “inoperable.” He later called this a “prehistoric way” of raising the frontal lobe and abandoned the frontal approach. Cushing also initially described the frontal approach as “inconceivably radical” (Fig. 1).[5] Horsley subsequently became an advocate of a subtemporal intradural approach and had performed several operations by this route by 1906.[3,4] Later, this approach found success and wide acceptance in the hands of other surgeons. Cushing was among the very few who had experience with the subtemporal approach to the sellar and suprasellar region, which he used until he began to perform direct transsphenoidal surgery for pituitary tumors in 1909.[6]

In 1900, Krause was the first to do an extradural subfrontal approach along the lesser sphenoid wing in an oblique fashion, rather than via the previously used straight direction beneath the elevated frontal lobe. This operative approach to remove a bullet in the region of the optic nerve was the first anterior approach in which the angle of direction was changed from a strict frontal toward the lateral frontal angle (Fig. 2).[7] Krause was quick to appreciate the significance of this procedure, and in the same year, he demonstrated a cadaver preparation with a suggested operative approach to the pituitary region that does not differ much from the frontal approach commonly used today.[8] He used this approach in 1905 for the removal of a fibrosarcoma in the region of the sella turcica and in 1909 for the removal of a pituitary tumor.[7]

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A few years later, in his 1914 Weir Mitchell Lecture, Cushing highlighted the difficulty he had during the subtemporal approach and the unsatisfactory results obtained from the subfrontal approach.[9]

In 1908, McArthur performed a modified intradural frontal approach similar to Krause's with an unsuccessful outcome. Thereafter, he changed his approach to an extradural one with a small frontal bone flap just above the eye that included the superior orbital rim and roof.[10, 11] This was probably the first cranio-orbital craniotomy technically similar to that currently used. Frazier pioneered the transition from transsphenoidal to transcranial surgery for pituitary tumors. His initial approach was a modification of McArthur's extradural approach, with the inclusion of the supraorbital ridge and the roof in the bone flap (Fig. 3).[12] Over the years, Frazier himself introduced many further modifications of his procedure, eventually eliminating the resection of the supraorbital ridge and the roof and using the intradural route.[13] He also preferred approaching from the side along the sphenoid wing to avoid excessive midline retraction of the frontal lobe, thus preventing impairment in the cerebral perfusion of the frontal lobe.

Heuer and Dandy: Towards a "pterional" approach

In 1914, Heuer, a contemporary of Cushing and Dandy, developed the first frontotemporal craniotomy with an intradural route to resect chiasmal lesions (Fig. 4).[14] This was the inception of today's widely used frontotemporal or "pterional" craniotomy. Dandy first described this approach in 1918, while Heuer was temporarily in France, clearly crediting Heuer for its creation, and the latter provided a detailed description when he came back to John Hopkins.[14, 15] Heuer's craniotomy was somewhat similar to Krause's previously described intradural frontolateral approach. The main differences were the position, which included both frontal and temporal bones, and the larger size of the bone flap. This approach was markedly different from and superior to the previous approaches in that it involved a shorter, oblique approach along the sphenoid ridge and resulted in wider exposure. The size and the position of the craniotomy "allowed for cerebral dislocation" and temporal retraction posteriorly to facilitate the exposure (Fig. 5). Heuer and Dandy used this approach on 24 patients between 1914 and 1918. Dandy later criticized Heuer's approach as having too large a bone flap and changed his technique to use a small, curved "concealed" incision behind the hairline with a small lateral frontal bone flap, now commonly referred to as a "Dandy flap" (Fig. 6).[16] He consistently used his version, which he called the "hypophyseal" approach, for the surgical treatment of chiasmal lesions and aneurysms of the anterior circulation. The need for a standardized basic bone flap was even more obvious by the mid-1940s, as increasing numbers of neurosurgeons became involved in the treatment of anterior circulation aneurysms following Dandy's successful attempts to clip intracranial aneurysms, which he is credited to have performed in 1937. Although there is enough overlap among the bone flaps reported, their categorization differed with some modifications.

Several of Dandy's contemporaries preferred uni- or bilateral frontal approaches to gain a more subfrontal access to the anterior circle of Willis. Falconer[17] used a unilateral frontal craniotomy for bifurcation aneurysms in the internal carotid artery (ICA) (Fig. 7). The exposure included mainly the frontal lobe. The author modified the anterior and posterior limbs of this craniotomy, so as to expose the superior sagittal sinus medially for anterior communicating aneurysms or the Sylvian fissure laterally for middle cerebral artery aneurysms, respectively. He also highlighted the importance of opening the Sylvian fissure and gently separating the frontal and the temporal opercula to reach the aneurysm. Similarly, Poppen[18] and Norlen and Barnum[19]

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used frontal bone flaps with slightly different skin incisions to provide a subfrontal exposure for accessing anterior communicating artery aneurysms (Fig. 8a,b). Hamby,[20, 21] too, favored the subfrontal approach with a unilateral frontal craniotomy for anterior circulation aneurysms except those originating in the middle cerebral artery (MCA) (Fig. 9a). He popularized the frontotemporal (frontolateral) craniotomy for MCA aneurysms to facilitate split of the Sylvian fissure to expose the carotid bifurcation as well as the MCA (Fig. 9b). Later, he modified this frontolateral approach for the treatment of orbital tumors and exophthalmos and called it the “pterional” approach (Fig. 10a),[22] a term that derives from the Greek root *pteron*, meaning "wing." In Greek mythology, Hermes, messenger of the gods, was enabled to fly by winged sandals, and wings on his head, which were attached at the pterion. In medicine, it has been used as a term to refer to a craniometric point in the region of the sphenoid fontanelle, at the junction of the greater wing of the sphenoid, the squamous temporal, the frontal, and the parietal bones; it intersects the course of the anterior division of the middle meningeal artery. Hamby’s description was probably the first use of this term to name a frontolateral approach and was the origin of the popular usage of the term for today’s standard frontotemporal craniotomy.

Although not as common, a temporal craniotomy was also used for anterior circulation aneurysms. Uihlein and Hughes,[23] Avman and Fisher,[24] and Poppen[25] preferred a temporal approach for ICA and MCA aneurysms, while Suzuki et al.[26-28] proposed the temporal approach with an unusual “temporal keel form incision” for ICA and MCA aneurysms.

Dandy’s trainees continued to utilize his concealed “hypophyseal” approach. One of Dandy’s students, Hayes, and his colleagues illustrated a frontotemporal approach that was referred to as a “small Dandy pituitary type of flap” to expose an anterior communicating artery aneurysm.[29] Another student of Dandy’s, Rizzoli, was coauthor of a report on the results of the

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surgical treatment of intracranial aneurysms using a frontotemporal craniotomy.[30] The commonly used modification of the pterional flap for anterior communicating artery aneurysms was described by Kempe, an associate of Hayes, and his colleagues (Fig. 10b).[31-33] They placed the critical burr hole at the junction of the temporal line, the zygomatic process of the frontal bone, and the orbital ridge, known as the "psychopathic point." The Sylvian fissure lies immediately beneath the center of and perpendicular to the curvilinear dural incision. The arachnoid is opened over the ICA and followed distally to its bifurcation.

Era of microsurgery, Yasargil, and standardization of anterior approaches

House et al.[34] pioneered the use of the microscope for the removal of vestibular schwannomas. Subsequently, Kurze and Doyle,[35, 36] Jacobson et al.,[37] Donaghy and Yasargil,[38] Rand and Kurze,[39] Pool and Colton,[40, 41] and Rand and Jannetta[42] reported various utilizations of the operative microscope in neurosurgery. Yasargil was one of the first to consistently use the operative microscope and popularize the microscopic technique.[1, 2, 43] The operative microscope enabled surgery to be done under higher magnifications and more luminous conditions. In addition to the operating microscope, the use of other components of microtechnique, including microinstruments, bipolar microcoagulation, and microdrills, made the concept of cisternal approach possible. This concept is basically defined as staying in cisterns, which are natural spaces between the lobes, without invading cerebral parenchyma as we approach the pathology. Through descriptions of the largest microneurosurgical series,[44-48] Yasargil and colleagues introduced the "keyhole" concept into neurosurgery, which included modification of the size of the bone flap and features that would offer new visualization under the microscope. In the initial description in 1969, a standardized frontotemporal craniotomy centered over the pterion was

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favored for aneurysms of all types located, especially, in the anterior circle of Willis. This route was relatively smaller but similar to those used by Hamby and Kempe as well as Dandy's trainees Hayes and Rizzoli. Yasargil and colleagues also drilled away the outermost part of the sphenoid wing extradurally,[1, 44] as did Dandy's trainees and others.[31, 49, 50] Yasargil referred to the sphenoid wing as "the key landmark" in the approach to the circle of Willis. The use of this bone flap, along with microsurgical techniques, would later enable him to popularize the dissection of the Sylvian cistern, and pioneer cisternal surgery especially as an approach to aneurysms.[51, 52] In refining his approach, Yasargil[45, 48] emphasized a lower basal exposure by drilling the sphenoid bone as far down as the superior orbital fissure, the orbital roof projections, and, occasionally, a part of the orbital ridge and the roof. He called this the frontolateral, spheno-orbital, or "pterional," approach (Fig. 11).[45, 48] In this version, he kept the same keyhole previously described as a "psychopathic point" and strategically placed 3 more burr holes, confining the bone flap to an even smaller and more frontosphenoidal location with a diamond shape. The approach mainly differed from previous approaches in being a more basal approach with a more pronounced sphenoid bone removal, a wider opening of the Sylvian fissure, and a remarkably smaller frontosphenoidal type flap. The skin incision for this approach was concealed behind the hairline, but descended low enough to enable a more basal approach. Yasargil applied this approach to clipping of basilar tip aneurysms with inclusion of removal of the anterior clinoid and, if necessary, posterior clinoid process as well.[51, 52]

Unlike the relative resistance shown to the use of strict frontal or lateral approaches in reaching the sellar and parasellar lesions, the introduction of the pterional technique was welcomed once Yasargil reported his early results (D.S. Samson, personal communication, 2012). The craniotomy characterized by a frontolateral approach appears to be a natural choice to achieve the aim of the least brain retraction necessary and the shortest surgical distance to the pathology. It has also been the approach for which most surgical modifications or refinements have been made to date.

In the recent era, Rhoton and colleagues have refined the fronto-temporal bone flap, with a precise method to place key burr holes. The MacCarty burr hole is the key hole used to simultaneously expose the anterior cranial fossa floor and the orbit in the supraorbital-pterional and orbitozygomatic approaches. Studies have defined simplified surgical landmarks to locate the ideal position of this key hole, approximately 5 mm behind and 7 mm above the frontozygomatic suture.[53, 54]

Several adjuncts have facilitated the exposure through the skull base approaches. Cerebrospinal fluid removal was one of these adjuncts to the other approaches, [55] especially Drake's subtemporal approach prior to the introduction of the pterional approach. Lumbar spinal drainage and pre- or intraoperative ventriculostomy helped facilitate all of the so-called skull base approaches when dealing with a swollen brain.[56] The use of osmotic diuretics was also well-established prior to the introduction of the pterional exposure (D.S. Samson, personal communication). On the other hand, the consistently wide opening of the sylvian fissure was an evolutionary contribution as well as an essential component of the pterional approach, as were the change in the angle (from strictly frontal to frontolateral or frontotemporal direction) from which it is approached and the frontotemporosphenoidal osteotomy. The cosmetic reconstruction was another factor in adoption of the approach. It was far more satisfactory after the introduction of a concealed skin incision behind the hairline by Dandy. This may also have resized the bone flap to a smaller one in comparison to that originally described by Heuer. Yasargil initially was concerned about the temporalis atrophy associated with a free bone flap and experimented with

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an attached flap (osteoplastic craniotomy), which seemed to produce a more pleasing cosmetic result (D.S. Samson, personal communication).

Variations of the pterional approach

During the past four decades, several reports have reviewed the pterional approach and offered slight modifications in the flap that were not disruptive;[57-62]. The size and shape of the craniotomy, the location of the burr holes (including the keyhole), the anterior or posterior extension of the craniotomy, and the degree of craniocaudal or anterolateral angle of approach based on the amount of bone removed anteriorly, posteriorly, or towards the skull base were modifications or refinements of the pterional approach. There was, and still remains, disagreement about the actual benefit derived from dropping the zygoma or removing the orbital roof, both techniques that had been tried and discarded by Yasargil (D.S. Samson, personal communication). However, several more significant variations or derivatives of pterional approach have also been described to overcome its limitations. A combined approach was first proposed by Drake et al.[63] to take advantage of pterional and subtemporal perspectives for posterior circulation aneurysms. Called the “half and half” exposure, it was, basically, a standard pterional craniotomy that was extended posteroinferiorly to expose the anterior aspect of the temporal lobe. Heros et al.[64] offered a slight modification that permitted a more anterior angle of vision offered by the pterional approach with the lateral line of vision offered by the subtemporal approach. These two variations were mainly aimed for the visualization of the basilar perforators hidden behind the aneurysm, and the contralateral PCA and and superior cerebellar artery. They also facilitated the proximal control for the low-riding basilar aneurysms. Sano et al.[65] described the temporopolar approach to aneurysms of the distal basilar artery. With this approach, the skin

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incision was the same as in Yasargil's pterional approach; the main difference was its temporal extension with an additional burr hole placed more posteriorly and inferiorly. Shiokawa et al.[66] added the removal of the zygomatic arch in cases of high-riding basilar tip aneurysms

Pellerin et al.[67] used an orbitofrontomalar approach with a bitemporal scalp incision, which basically was a fronto-orbitozygomatic flap with the superior orbital ridge included. The removal of the flap was followed by excision of the lesser and greater sphenoid wings as needed. Hakuba et al.[68, 69] described the orbitozygomatic infratemporal approach with a bicoronal skin incision, in which a new bone flap was devised by expanding the boundaries of the classic pterional approach. This flap included three separate pieces—an orbitofrontotemporal and an orbitozygomatic, followed by a greater sphenoid wing flap. Orbitofrontomalar and orbitozygomatic infratemporal approaches provided good access to the high-riding basilar aneurysms and to the tumors with significant rostral extension into the 3rd ventricle. In 1987, Dolenc pioneered the transcavernous–trans-sellar approach to basilar tip aneurysms.[70] This approach evolved from his combined epi- and subdural direct approach to carotid–ophthalmic artery aneurysms.[71] Again, the bone flap was formed by a classical pterional craniotomy with differences in complete removal of the sphenoid wing along with the roof of the orbit as well as the anterior and posterior clinoidal processes. Al-Mefty[72] included the superior and lateral orbital rims, the anterior portion of the orbital roof, and the adjacent frontal and temporal bones in the flap in his supraorbital-pterional approach and also drilled the sphenoid wing to the base of the anterior clinoidal process. De Oliveira et al.[73] reported their pretemporal approach to the interpeduncular cistern and petroclival region. In their approach, they basically used a frontotemporal craniotomy very low in the middle fossa, which exposed the temporal lobe completely. They concluded that this approach combined the advantages of both the classic

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pterional and the subtemporal approaches. Hernesniemi et al.[74] proposed the lateral supraorbital approach as an alternative to the classical pterional approach. They generally used a single burr hole below the insertion line of the temporalis muscle and shifted the pterional flap towards the frontal side. The sphenoid ridge was drilled off and the Sylvian fissure was left just on the temporal edge of the craniotomy and opened from the frontal side.

Conclusion

Today's standardized anterior cranial approaches have evolved from Krause's unilateral subfrontal to Heuer and Dandy's frontotemporal and then to Yasargil's frontolateral, spheno-orbital, or, "pterional" approach. The original pterional approach has been further modified with derivative approaches that overcome particular surgical obstacles with different pathological conditions. With the numerous variations available, this versatile approach has been and will continue to be the most commonly used cranial approach for years to come.

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Figure Legends

Figure 1: Illustrations of Cushing's transfrontal approach. A, position of the bone flap. B, the retraction of the frontal dura mater off the orbital roof and the sphenoid ridge. C, the exposure of the right optic nerve and the lesion. Reproduced from Cushing and Eisenhardt (1929).[75]

Figure 2: Illustration showing Krause's frontolateral approach, which uses a more lateral perspective to the parachiasmatic lesions than the unilateral transfrontal approaches. Reproduced from Krause (1909-1912).[7]

Figure 3: Illustrations of the transfrontal approach described by Frazier. A, orbital ridge between the lines (a) and (b) along with a portion of the orbital roof were temporarily removed. B, the frontal lobe was retracted extradurally. Reproduced from Frazier (1913).[12]

Figure 4: Illustration of the frontotemporal approach used by Heuer showing the oblique exposure of the optic nerve and tumor. Reproduced from Heuer (1920).[14]

Figure 5: Illustration of the frontotemporal ("hypophyseal") approach to an aneurysm used consistently by Heuer and Dandy. Reproduced from Dandy (1939).[76]

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Figure 6: Illustration showing Dandy's modification of the "hypophyseal" approach with the concealed skin incision (behind the hairline) and a smaller size craniotomy. Reproduced from Dandy (1932).[16]

Figure 7: Illustration showing Falconer's unilateral frontal approach to anterior communicating artery aneurysms. Reproduced from Falconer (1951).[17]

Figure 8: a) Illustration showing Poppen's unilateral subfrontal approach to anterior communicating artery aneurysms. Reproduced from Poppen (1960).[25] b) Illustration of Norlen and Barnum's unilateral subfrontal approach to anterior communicating artery aneurysms. Reproduced from Norlen and Barnum (1953).[19]

Figure 9: a) Illustration depicting Hamby's frontolateral approach to ICA aneurysms. b) Illustration depicting Hamby's frontotemporal approach to MCA aneurysms. Reproduced from Hamby (1952).[20]

Figure 10: a) Illustration depicting Hamby's "pterional" approach for orbital tumors and exophthalmos. Reproduced from Hamby (1964).[22] b) Illustration showing Kempe's frontolateral flap for anterior communicating artery, ICA, and MCA aneurysms. Reproduced from Kempe (1968).[31]

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Figure 11: Illustration showing the frontosphenoidal type flap as popularized by Yasargil for most of the anterior circulation aneurysms as well as the sellar and parasellar lesions. Reproduced from Fox (1983).[49]

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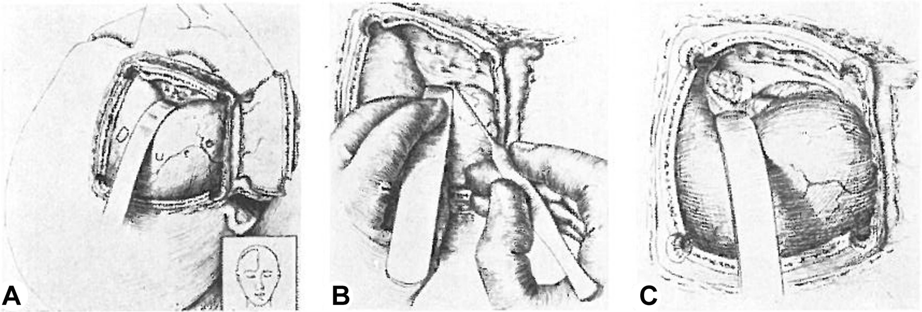
A
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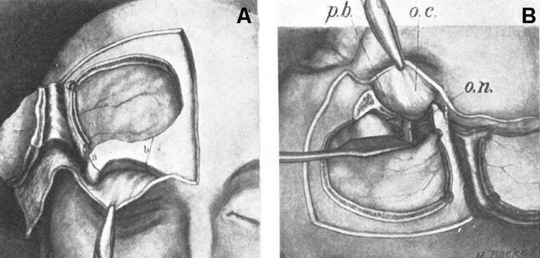
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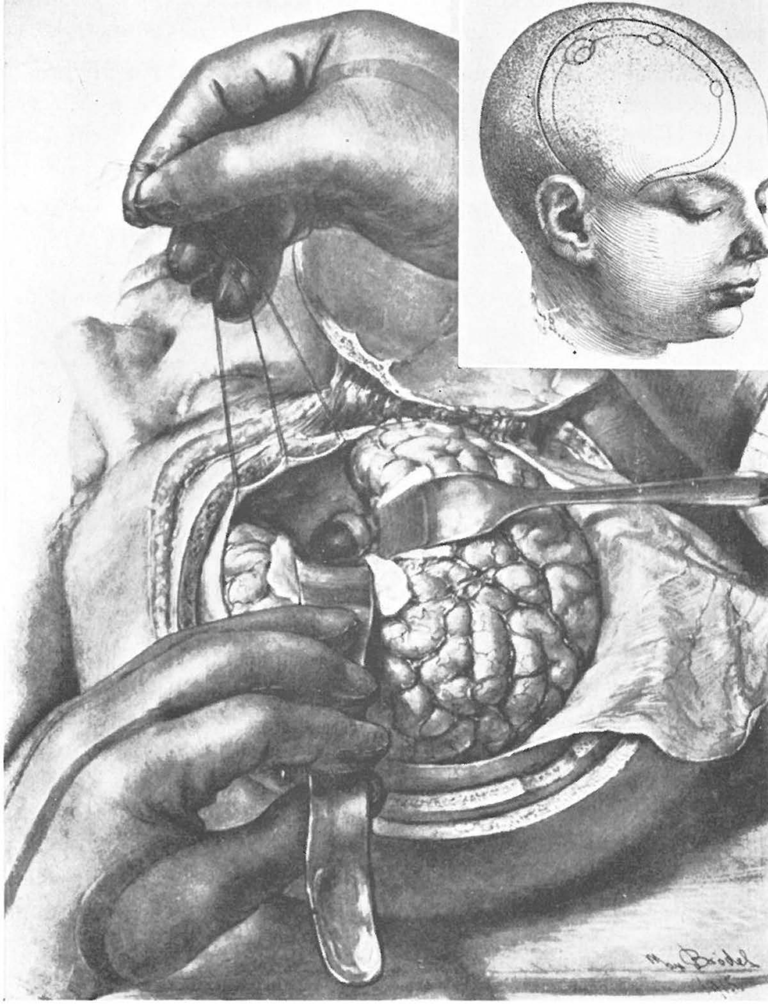
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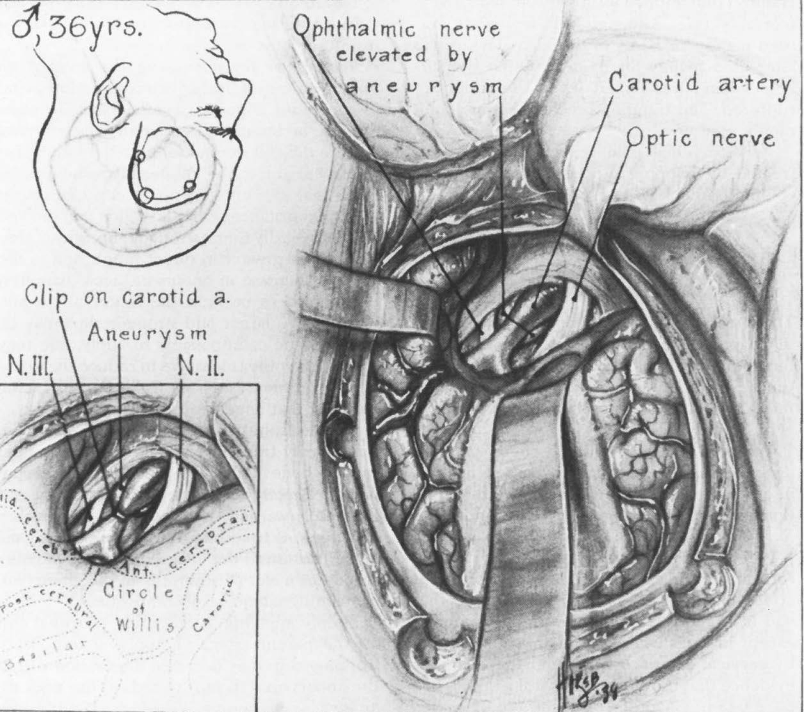
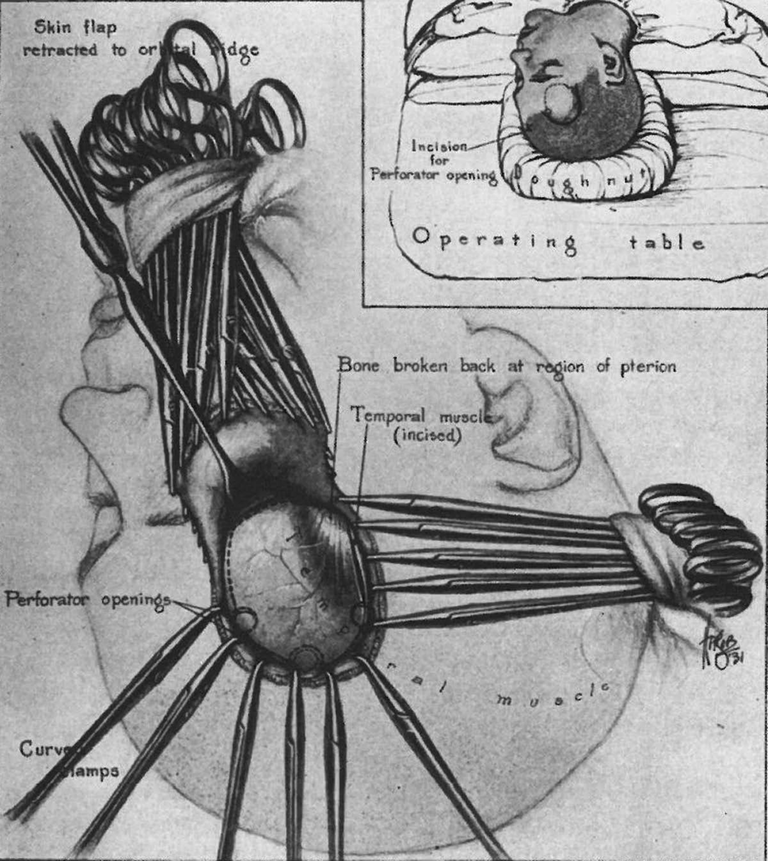
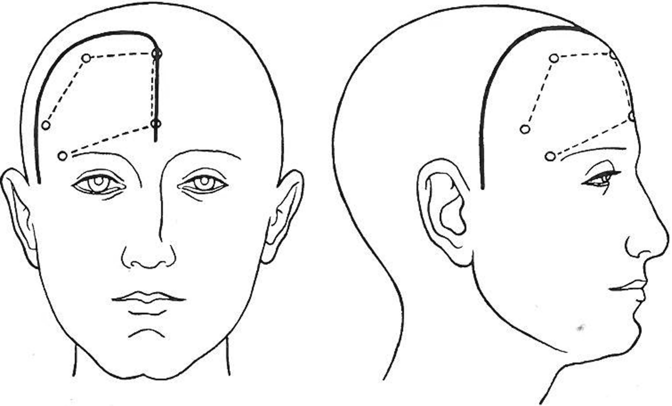
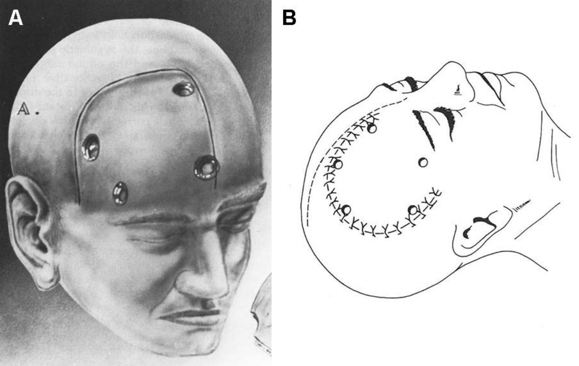

♂, 36yrs.
Ophthalmic nerve elevated by aneurysm
Carotid artery
Optic nerve
Clip on carotid a.
Aneurysm
N. III.
N. II.
cerebral
Ant. cerebral
Circle of Willis
Post. cerebral
Carotid
Basilar


Skin flap
retracted to
Incision
for
Perforator opening
Dough nut
Operating table
Bone broken back at region of pterion
Temporal muscle
(incised)
Perforator openings
muscle




A
A.
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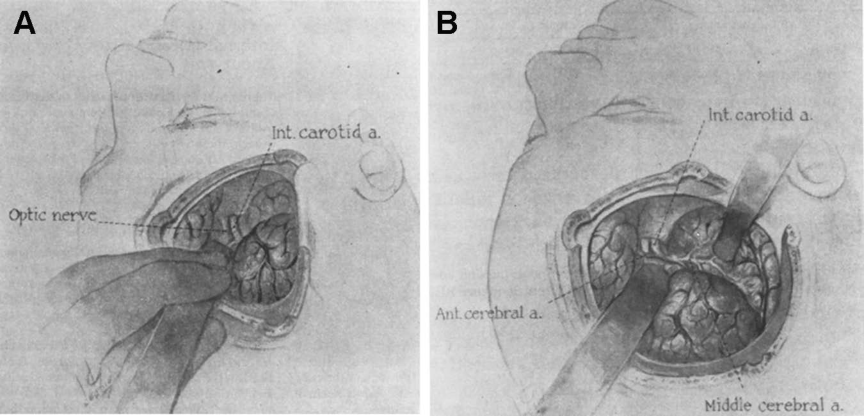
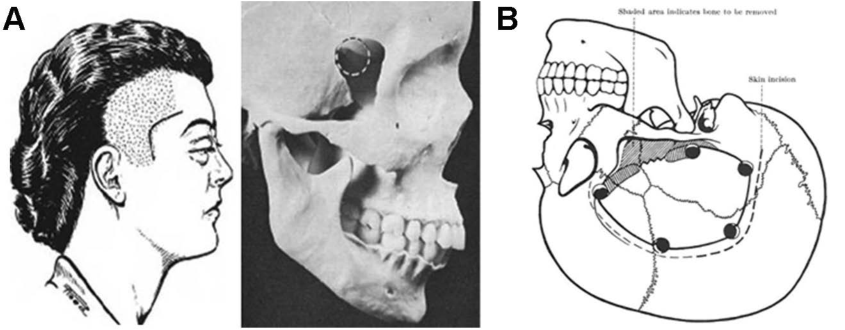

A
Int. carotid a.
Optic nerve
B
Int. carotid a.
Ant. cerebral a.
Middle cerebral a.


A
B
Shaded area indicates bone to be removed
Skin incision